

CLAIMS

1. An x-ray detector for fluoroscopy comprising:
 - a. a screen configured to convert x-rays into photons;
 - b. an array of image sensors positioned behind the screen and having at
5 least one output for connection to a computer or other electronic imaging processor,
each of said image sensors comprising a plurality of photosensor pixels; and
 - c. a demagnification lens system positioned between the screen and the
array of image sensors and configured to transfer photons emitted by the screen to the
array of image sensors, said lens system comprising an array of individual lenses;
- 10 wherein:
 - d. the lens system is quantum limited in operation and able to transfer
very low levels of photons from the screen to each photosensor pixel; and
 - e. each image sensor is configured to detect very low levels of photons.
2. The x-ray detector for fluoroscopy of Claim 1 wherein each image sensor is a
15 CCD image sensor having an on-board gain mechanism in the form of an extended section of
gain register located before an image sensor output, said extended section of gain register
comprising a plurality of stages controllably clocked to produce a slight and well-controlled
avalanche charge multiplication process, and, thereby, a slight gain per stage.
3. The x-ray detector for fluoroscopy of Claim 2 wherein the photosensor pixels
20 of each image sensor are non-avalanche multiplication photodiodes.
4. The x-ray detector for fluoroscopy of Claim 1 wherein the photosensor pixels
of each image sensor are non-avalanche multiplication photodiodes.
5. The x-ray detector for fluoroscopy of Claim 1 wherein the lens system is
configured to transfer from the screen to the array of image sensors at least ten photons per
25 photosensor pixel per frame at 30 frames-per-second fluoroscopy.
6. The x-ray detector for fluoroscopy of Claim 1 wherein:
 - a. the image sensors are CCD image sensors;
 - b. the photosensor pixels are non-avalanche multiplication photodiodes;and
- 30 c. the CCD image sensors each have an onboard CCD gain section,
positioned before an output stage, that acts as a charge amplifier for boosting signal
levels and reducing noise.
7. The x-ray detector for fluoroscopy of Claim 1 wherein the lens system has an
optimized demagnification ratio for providing quantum-limited operation.

8. The x-ray detector for fluoroscopy of Claim 1 wherein there are an equal number of individual lenses and image sensors, and wherein the number of individual lenses is selected from the group consisting of: four lenses in a 2x2 array; nine lenses in a 3x3 array, and sixteen lenses in a 4x4 array.
- 5 9. The x-ray detector for fluoroscopy of Claim 1 wherein the array of image sensors is enclosed in a thermally-insulated, gas-sealed enclosure that is cooled by a heat removal system.
- 10 10. A quantum-limited x-ray detector for fluoroscopy comprising:
- a. a screen configured to convert x-rays into photons;
 - 10 b. a demagnification lens system positioned behind the screen; and
 - c. an array of CCD image sensors optically coupled to the screen by the lens system, said array of image sensors having at least one output for connection to a computer or other electronic imaging processor, and each of said image sensors comprising a plurality of non-avalanche multiplication photosensor pixels; wherein:
 - 15 d. the lens system is quantum limited in operation for transferring from the screen to the array of image sensors at least ten photons per photosensor pixel per frame for 30 frames-per-second fluoroscopy; and
 - e. each CCD image sensor has an onboard CCD gain section, positioned before an output stage, that acts as a charge amplifier for boosting signal levels and reducing noise.
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11. The quantum-limited x-ray detector of Claim 10 wherein the gain section of each CCD image sensor comprises an extended gain register having a plurality of stages controllably clocked to produce a slight and well-controlled avalanche charge multiplication process, and, thereby, a slight gain per stage.
- 25 12. The quantum-limited x-ray detector for fluoroscopy of Claim 11 wherein the array of CCD image sensors is enclosed in a thermally-insulated, gas-sealed enclosure that is cooled by a heat removal system.
13. The quantum-limited x-ray detector for fluoroscopy of Claim 10 wherein the array of CCD image sensors is enclosed in a thermally-insulated, gas-sealed enclosure that is cooled by a heat removal system.
- 30 14. A quantum-limited x-ray imager for fluoroscopy comprising:
- a. an x-ray conversion screen for converting at least a portion of the x-rays received at an input side of the screen to photons at an output side of the screen; and

b. a plurality of image sensors optically coupled to the photon output side of the screen by a lens system, wherein: each image sensor comprises a plurality of non-avalanche multiplication image sensor pixels; the lens system has an optimized demagnification ratio for quantum-limited operation and is configured to provide to the image sensor pixels a minimum light signal of at least one photon per x-ray conversion in the screen per frame for 30 frames-per-second fluoroscopy; and the images sensors have an on-board, low-noise electrical gain or amplification mechanism for detecting the minimum light signal.

15. The quantum-limited x-ray imager for fluoroscopy of Claim 14 wherein the array of image sensors is enclosed in a thermally-insulated, gas-sealed enclosure that is cooled by a heat removal system.

16. The quantum-limited x-ray imager for fluoroscopy of Claim 14 wherein: the image sensors are CCD image sensors; and the electrical gain or amplification mechanism of each CCD image sensor comprises an extended gain register having a plurality of stages controllably clocked to produce a slight and well-controlled avalanche charge multiplication process, and, thereby, a slight gain per stage, which, when multiplied by the number of gain register stages, produces an amplified detection signal greater than the input noise level of an output stage of the CCD image sensor, even when the CCD image sensors receive only the minimum light signal.

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